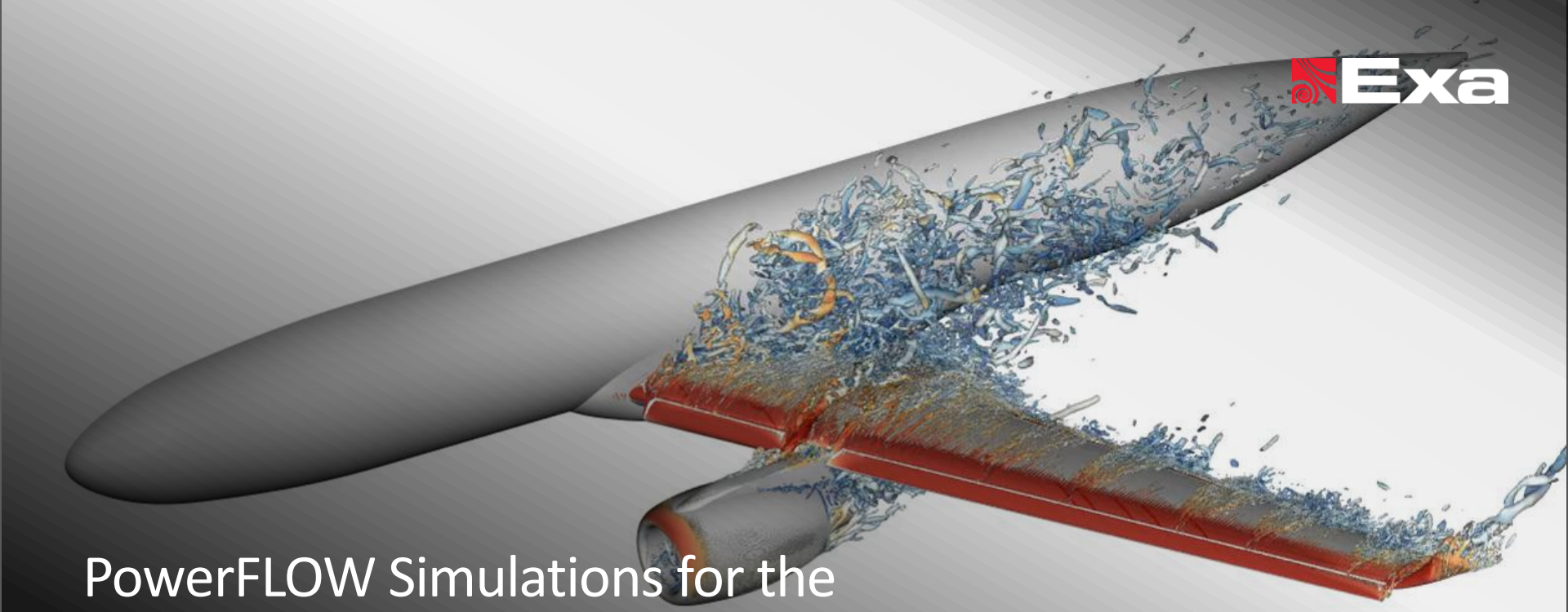


PowerFLOW Simulations for the Third AIAA High Lift Prediction Workshop

AIAA SciTech 2018, January 10

Benedikt König, Ehab Fares (Exa GmbH) and Mitsuhiro Murayama, Yasushi Ito (JAXA)

Agenda

1 Introduction of the Method

2 Grid Convergence

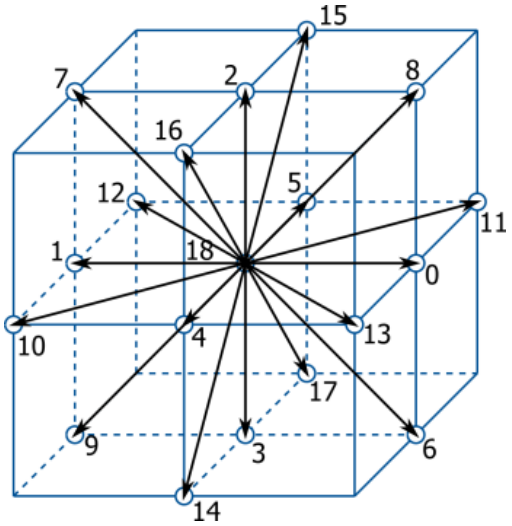
3 JSM - Nacelle/Pylon Effect

4 JSM - Stall Behavior Analysis

5 Summary and Outlook

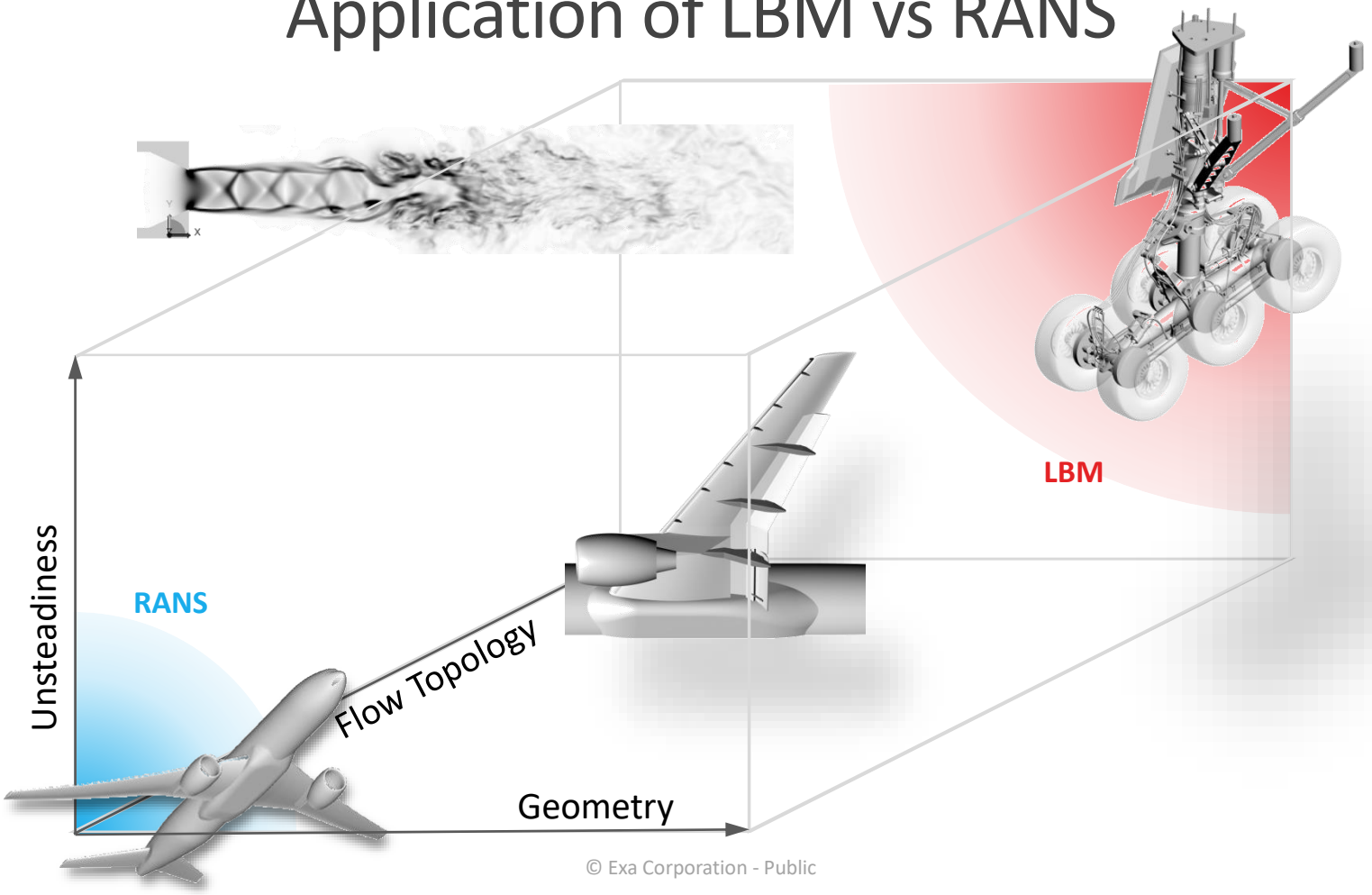
Lattice Boltzmann Method - PowerFLOW

- Discretization
  - Limited set of discrete particle velocities
  - Inherently unsteady
- Turbulence Modelling
  - Compute coherent, anisotropic structures
  - Model universal, isotropic structures
  - Two equation k-ε model (extended RNG)
- Grid Approach
  - Automatic Cartesian grid generation
  - Wall function
- Extensions to High Subsonic and Transonic Regime

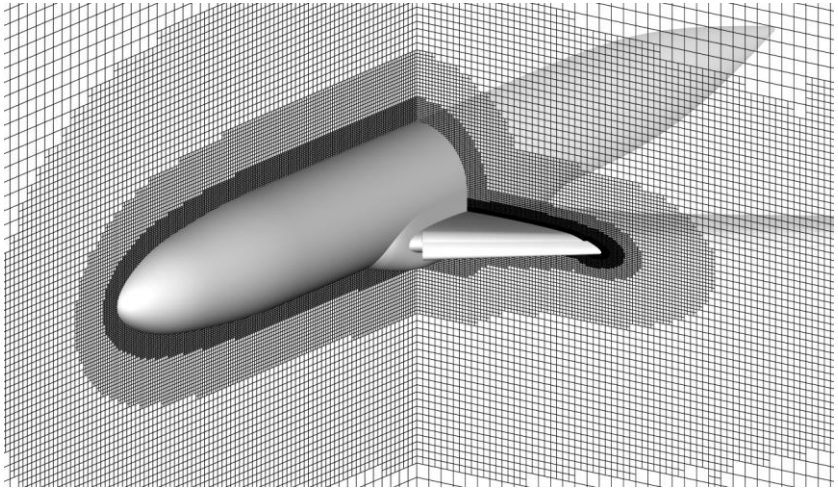


D3Q19 Model

Application of LBM vs RANS

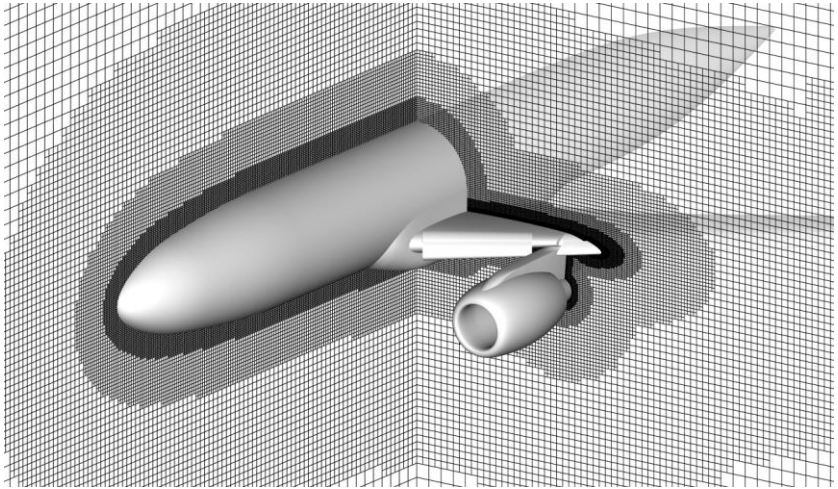


Lattice Boltzmann Method – Mesh



Grids coarsened for visualization

Lattice Boltzmann Method – Mesh



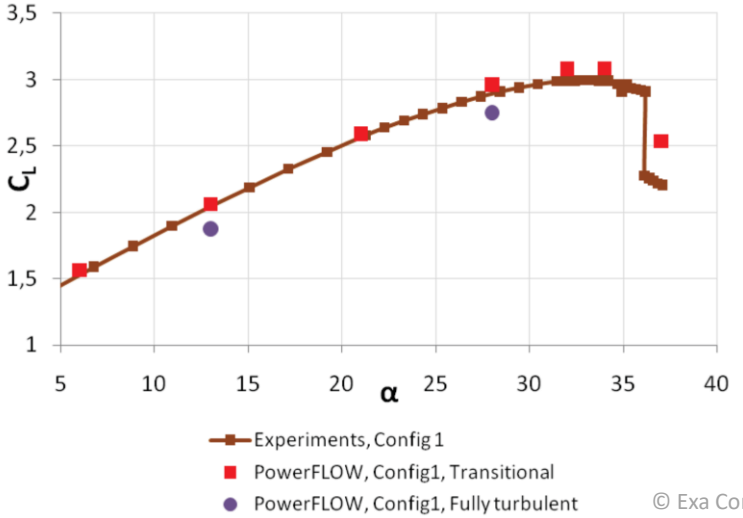
Grids coarsened for visualization

- Cartesian Mesh
- Automatic generation for arbitrarily complex geometries

Case	Number of Voxels	Number of Surfels
2a	125×10^6	14.9×10^6
2c	138×10^6	18.0×10^6

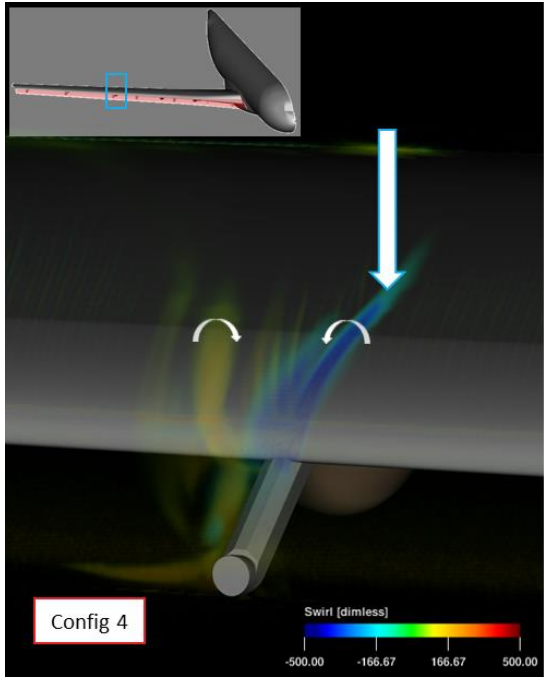
Previous Work – HiLiftPW-1

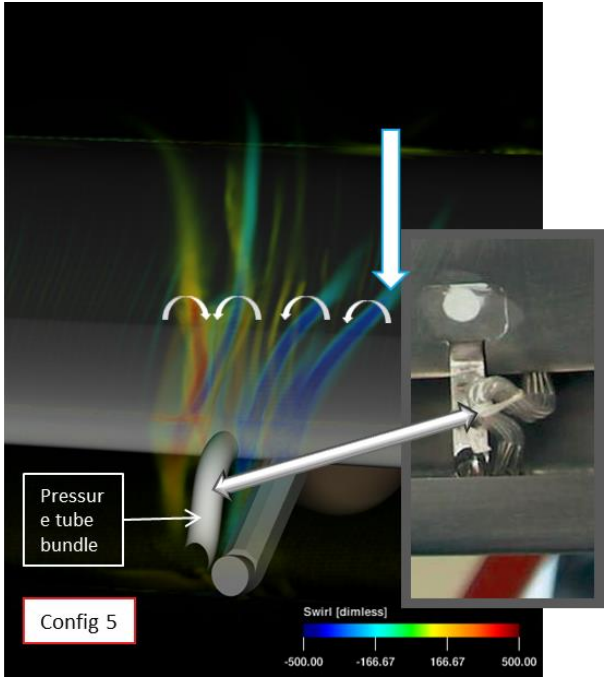
- NASA Trap-Wing
- Investigated:
  - Geometrical fidelity (brackets on/off)
  - Transition
  - Wind tunnel installation & hysteresis effects



Previous Work – HiLiftPW-2

- DLR-F11
- Investigated:
  - Reynolds Number effects
  - Geometrical fidelity (pressure tubes on/off)
  - Transition
  - Wind tunnel installation effects





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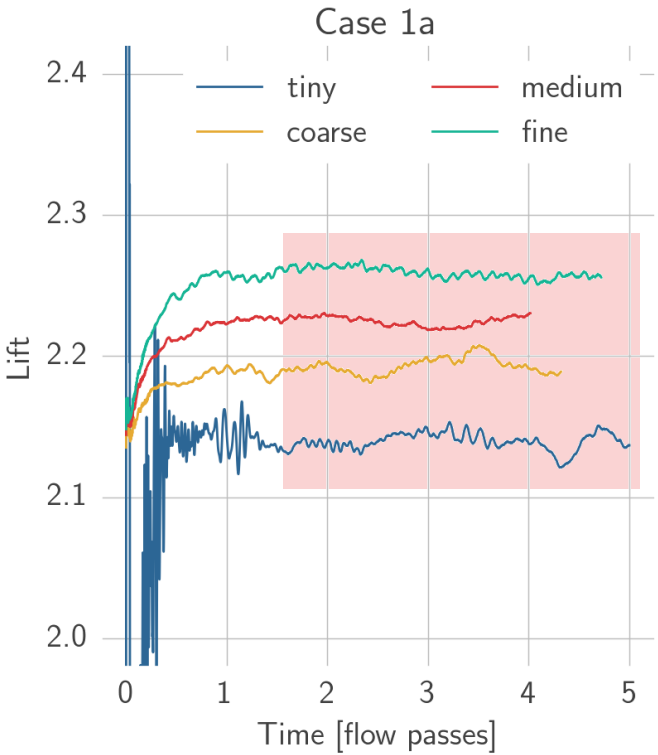
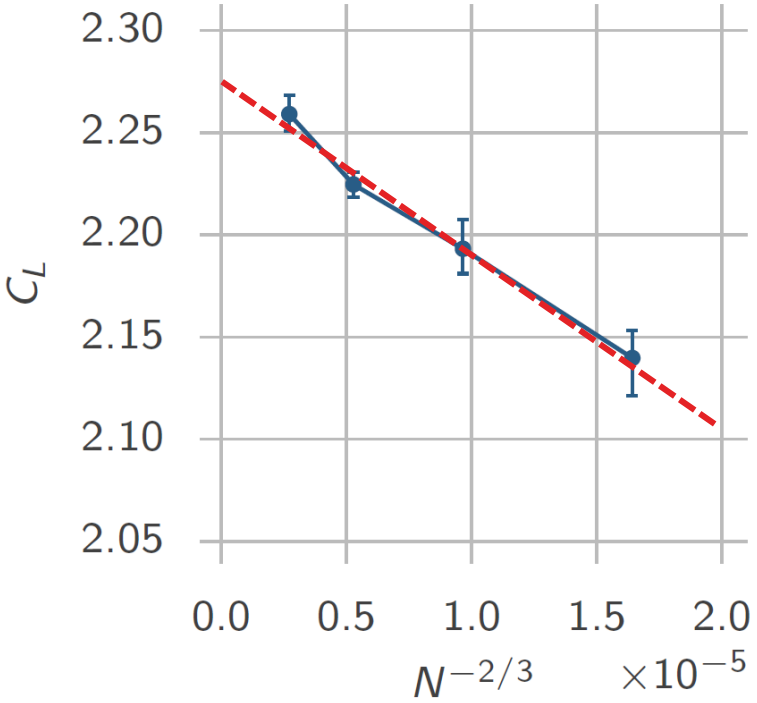
Grid Convergence Study on CRM

- Simulated case 1a at α=16°:
  - Significant unsteadiness requires longer averaging than expected
- Long period fluctuations
- Grid convergence assessment based on available data
  - Averaging start at t = 1.5 sec (~1.6 flow passes)



Grid Convergence Study on CRM

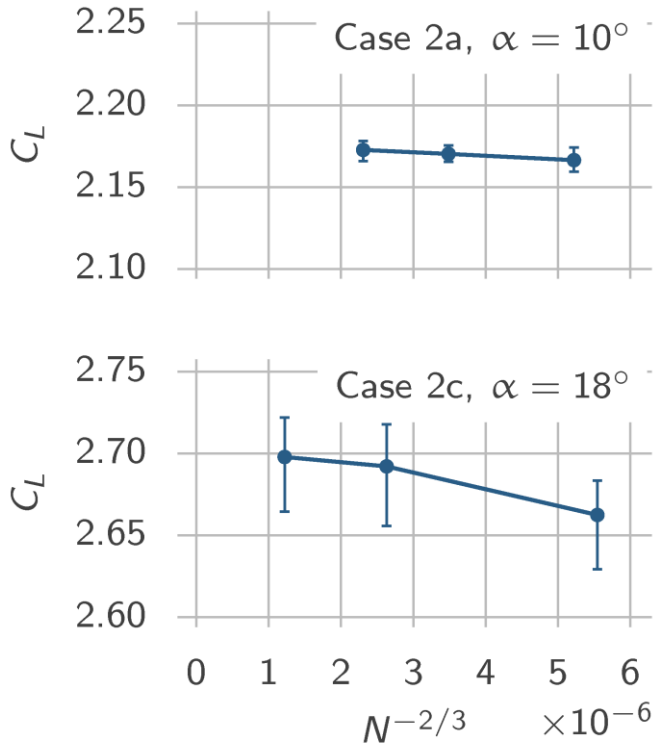
- Error bars indicate range of fluctuations within available signal
- Fluctuations most likely linked to unsteady slat cove vortex behaviour (see paper for more information)
- Linked to
  - Geometry
  - Flow condition
- Nearly straight behaviour achieved, similar to second order accuracy



Grid Convergence Study on JSM

- Alternative study conducted on JSM
- Two angles-of-attack
  - 10° → simple flow topology
  - 18° → complex flow topology (near $C_{L,max}$)
- Convergence behaviour differs significantly with flow complexity

→ vortex- and separation-dominated flows affect grid convergence



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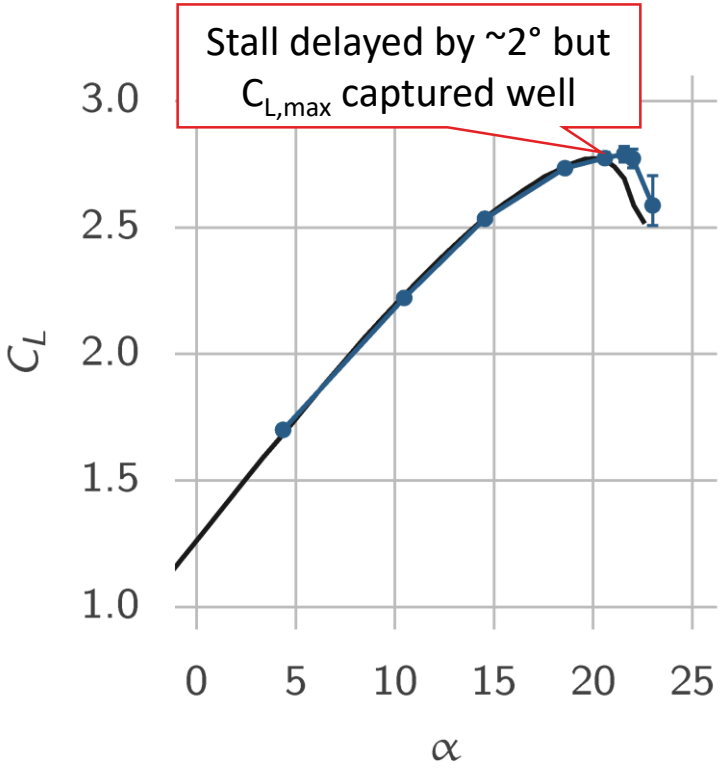
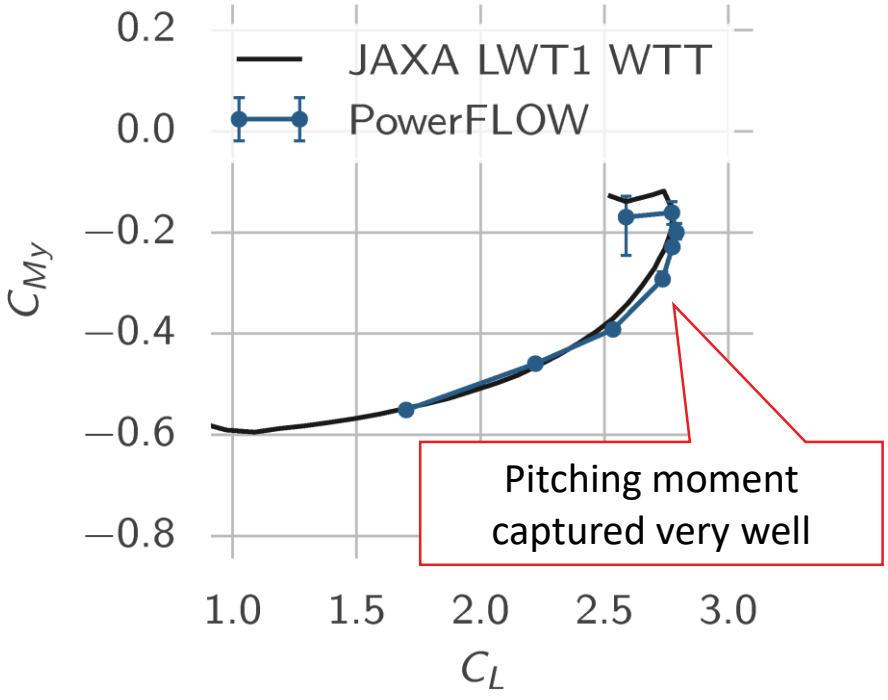
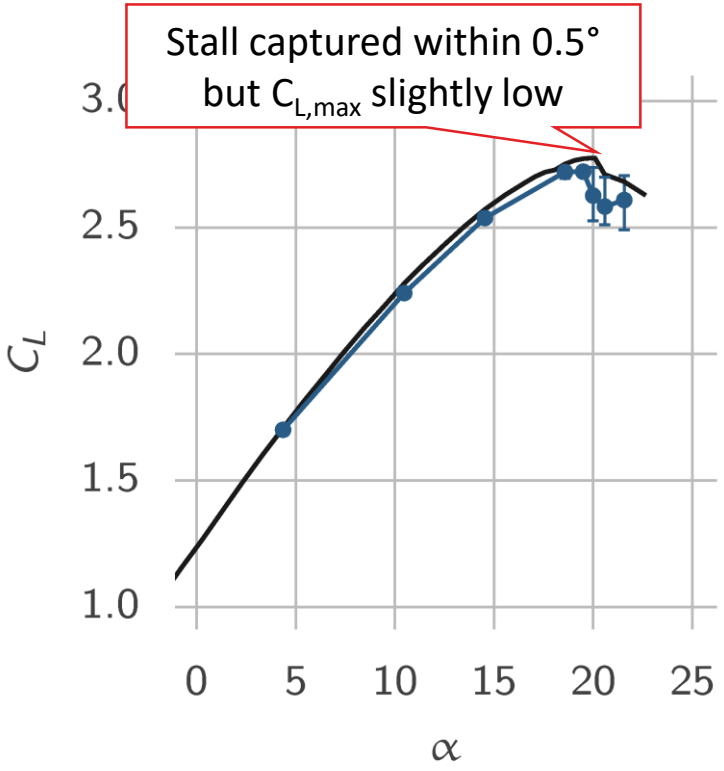
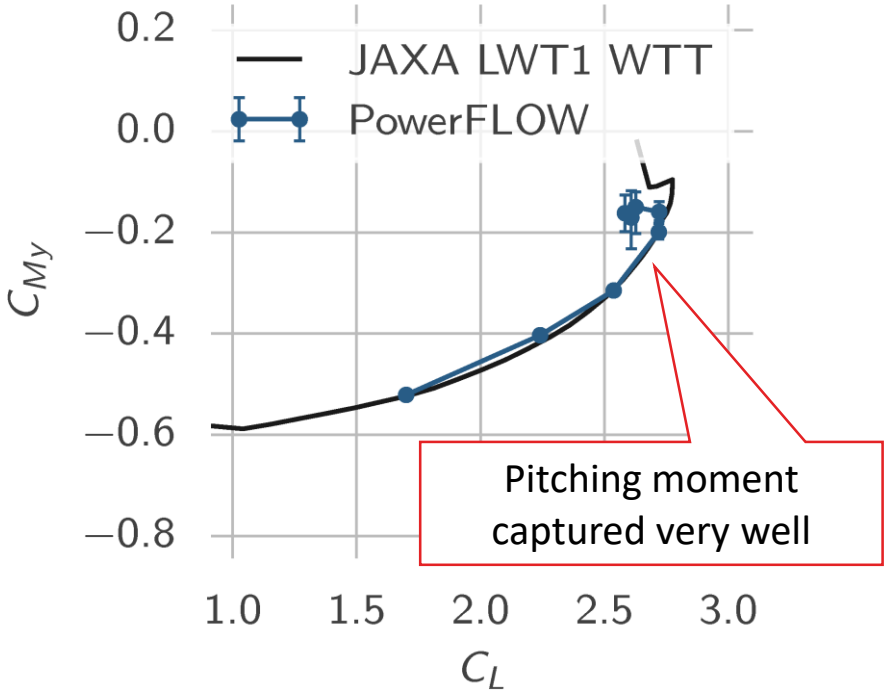
Case 2a – Nacelle/Pylon Off





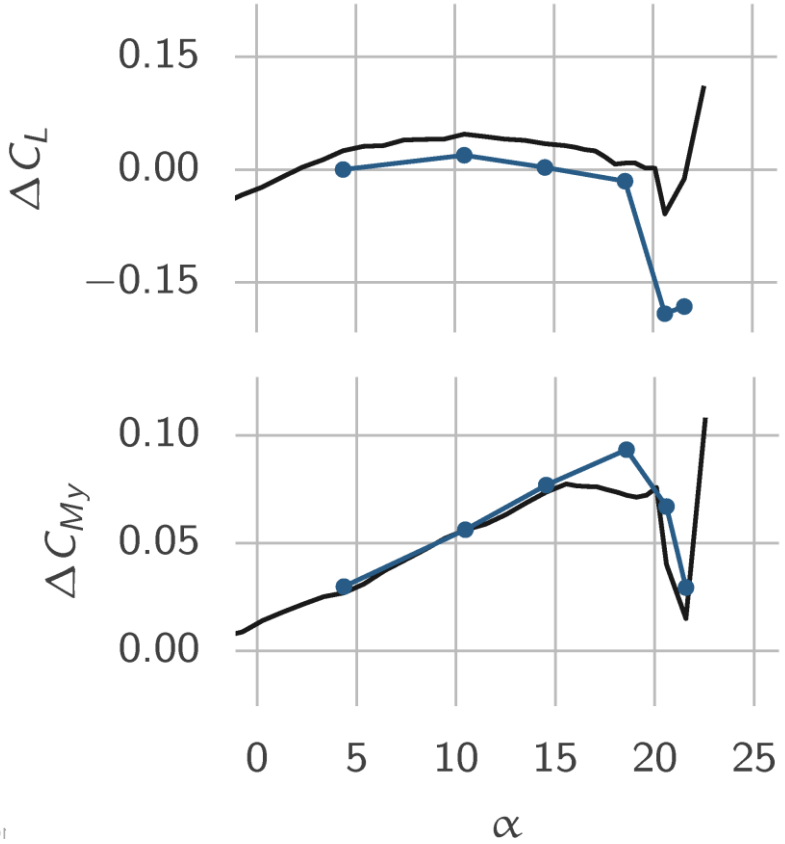
Case 2c – Nacelle/Pylon On



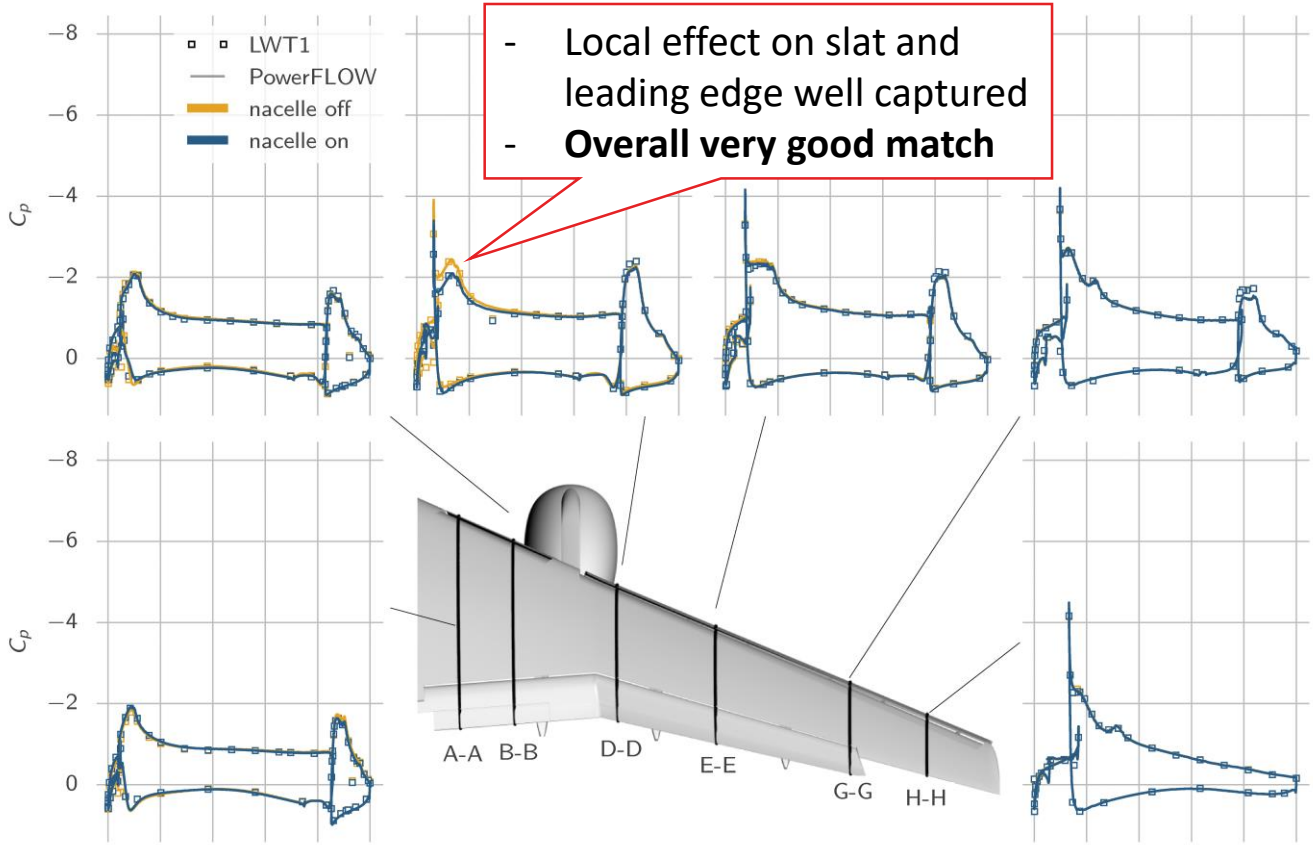


Installation Effect - Forces

- Trends captured very well



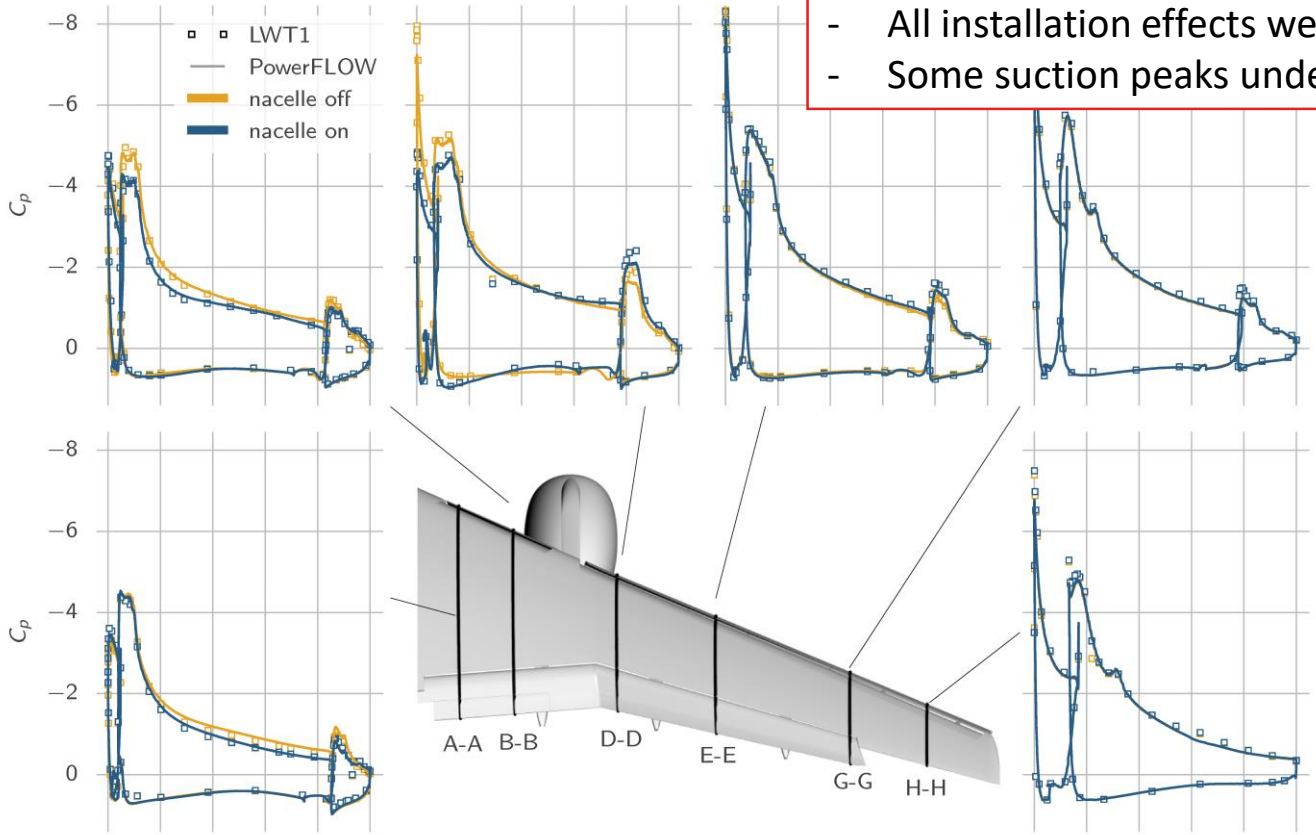
Installation Effect – C_p @ 4.36°



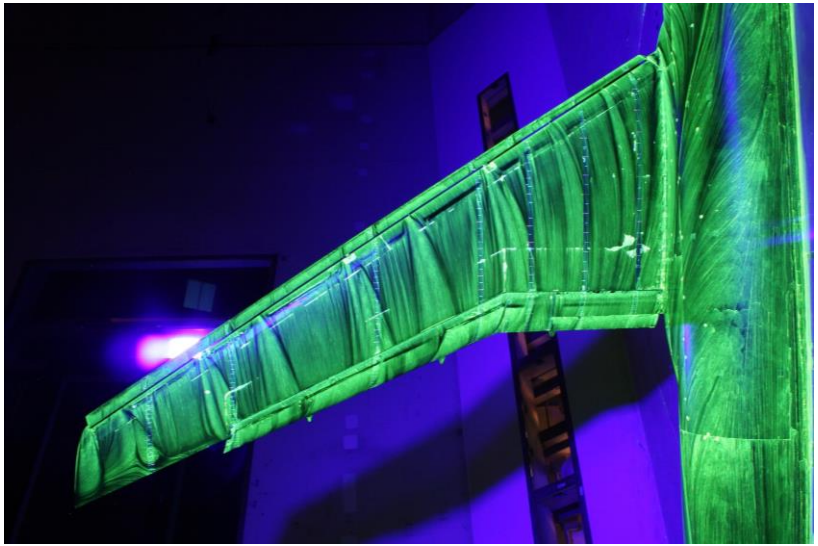
- Local effect on slat and leading edge well captured
- **Overall very good match**

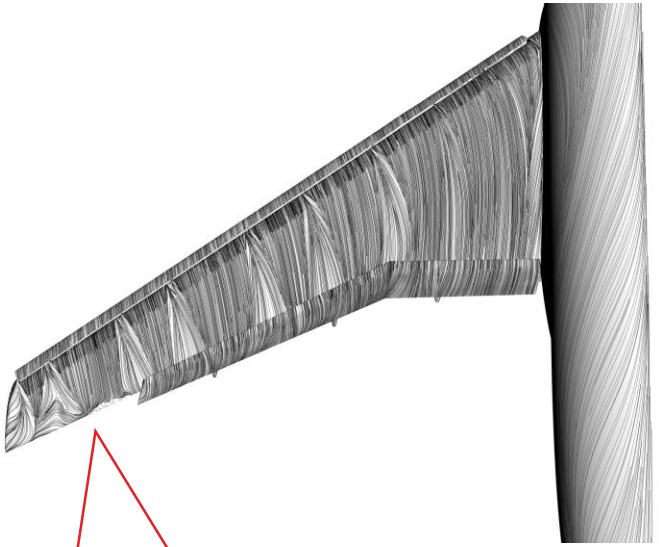
Installation Effect – C_p @ 18.58°

- All installation effects well captured
- Some suction peaks under-predicted



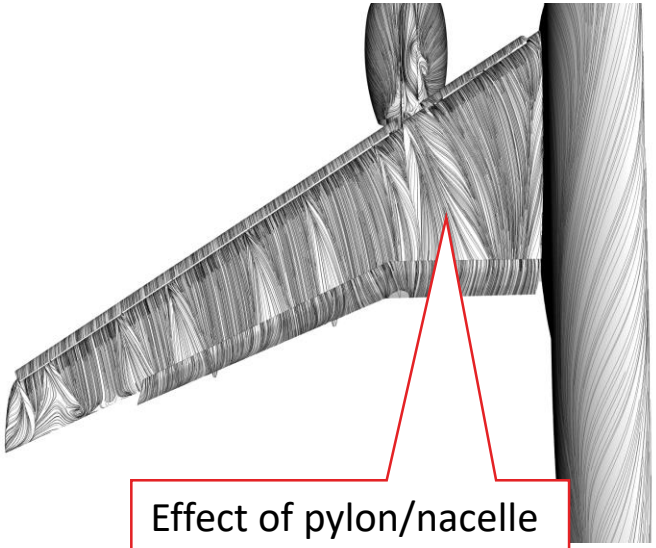
Case 2a – Nacelle/Pylon Off – 18.58°





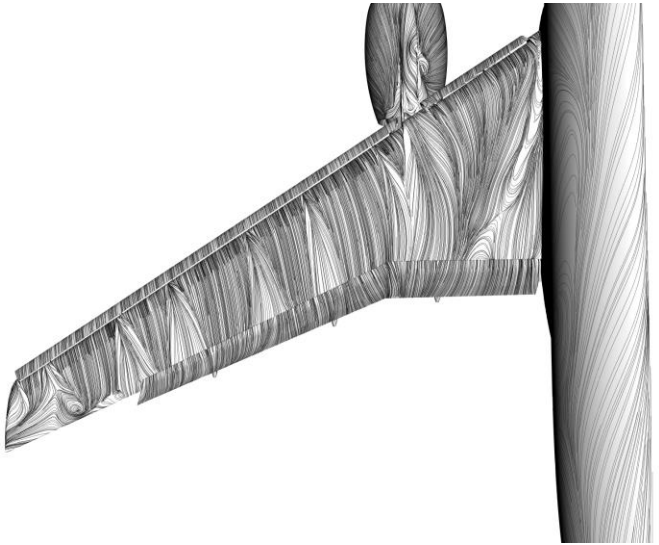
Local flow structures very well captured

Case 2c – Nacelle/Pylon On – 18.58°



Effect of pylon/nacelle reproduced

Case 2c – Nacelle/Pylon On – 21.57°



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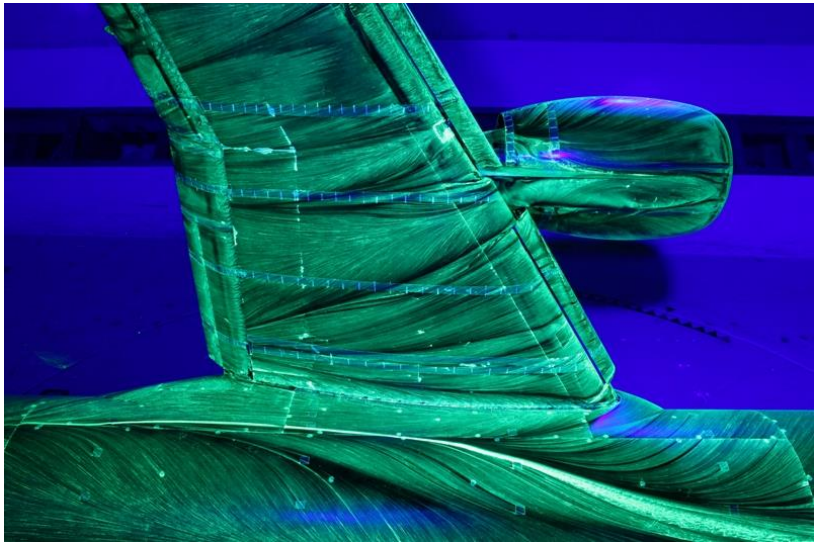
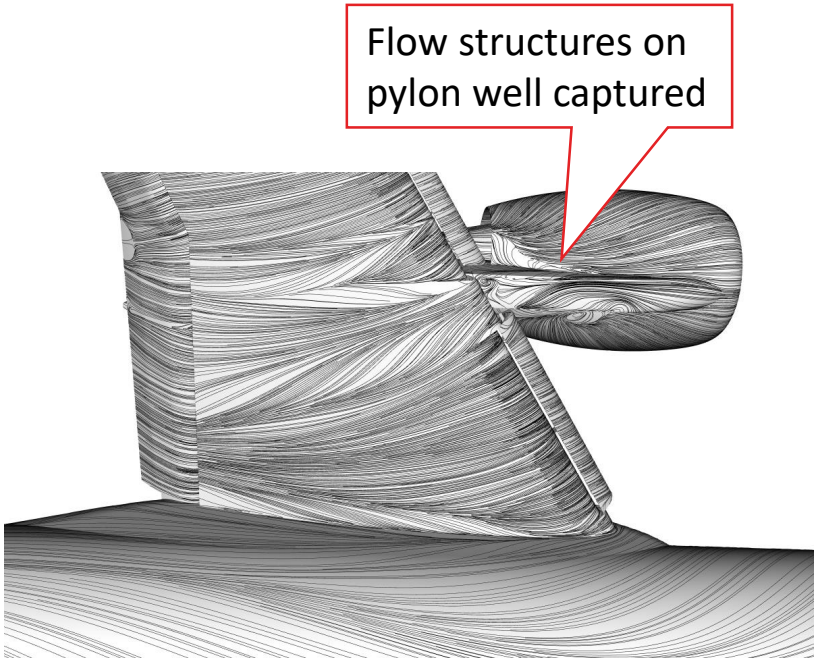
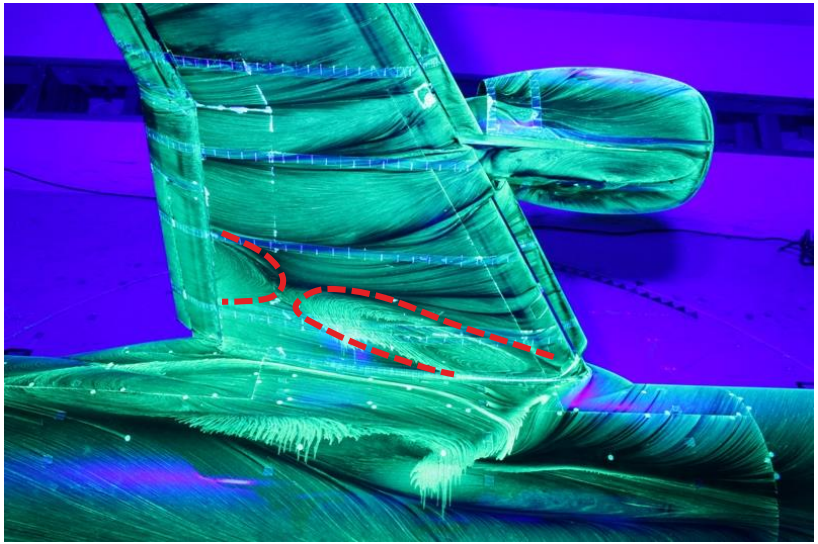
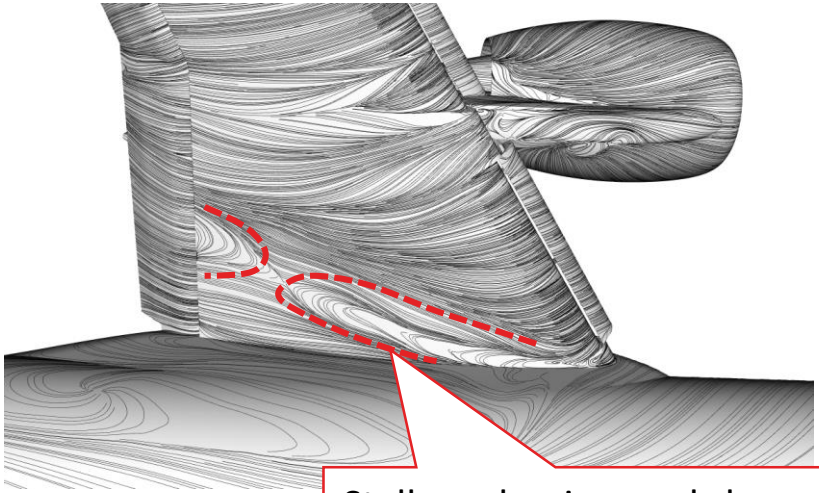
Pre-Stall – 18.58°





Post-Stall – 21.57°

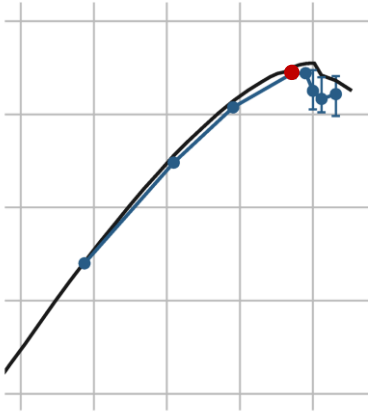


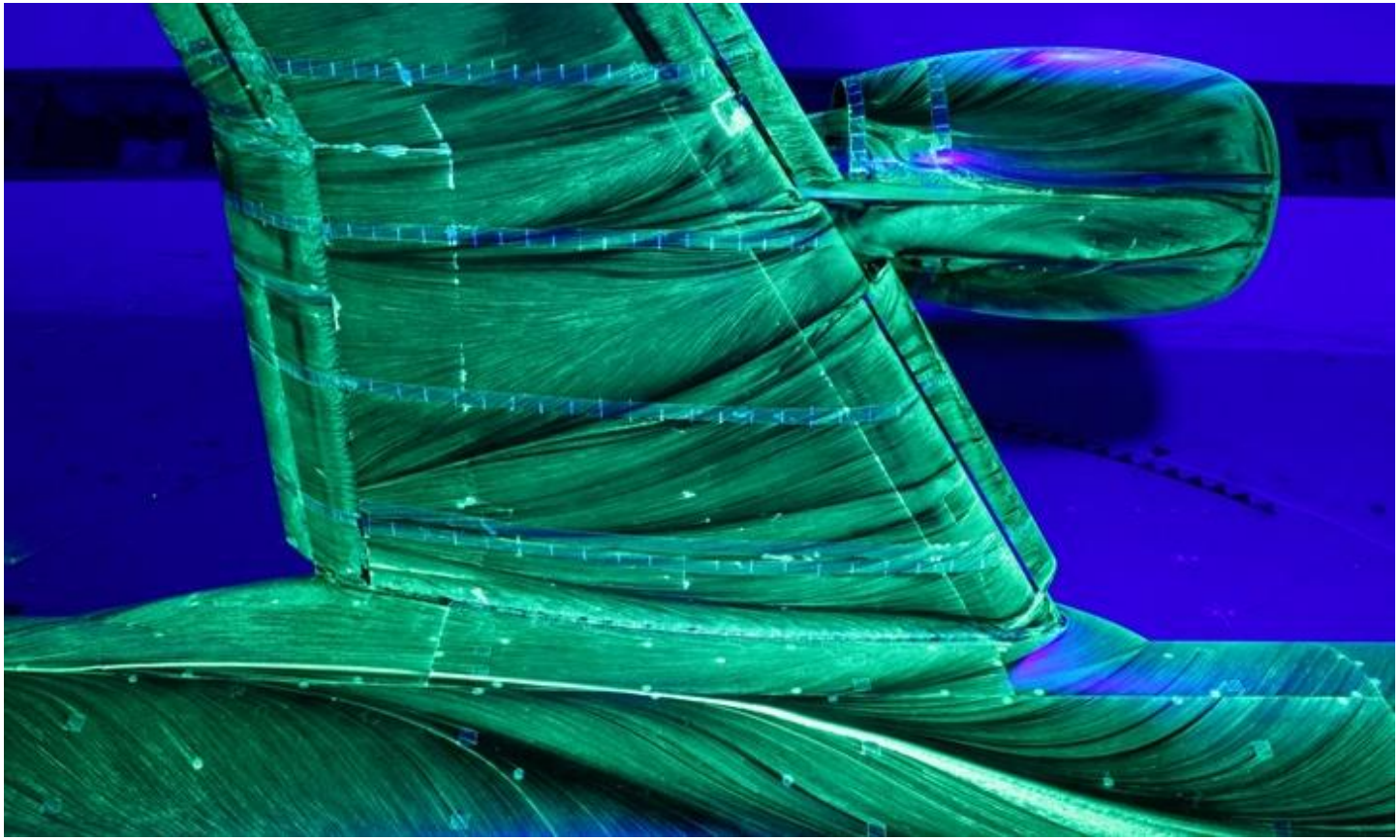


Stall mechanism and shape of separation very well captured

Stall Progression

Use CFD solution to illustrate stall progression





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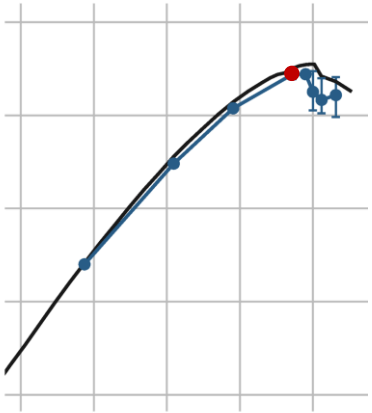

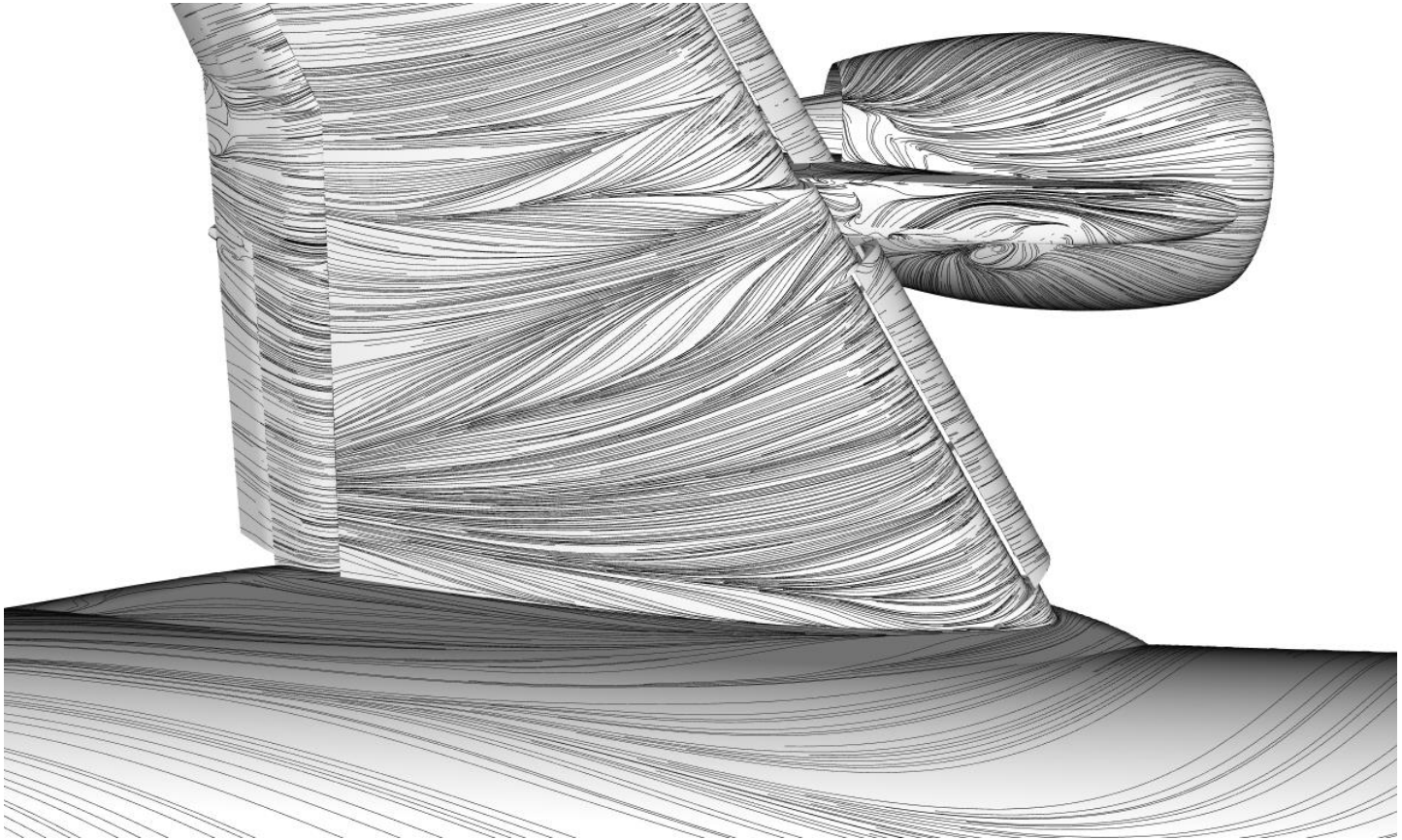

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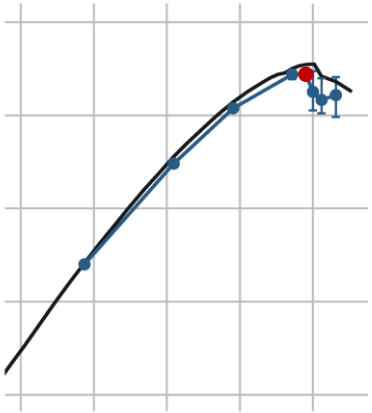

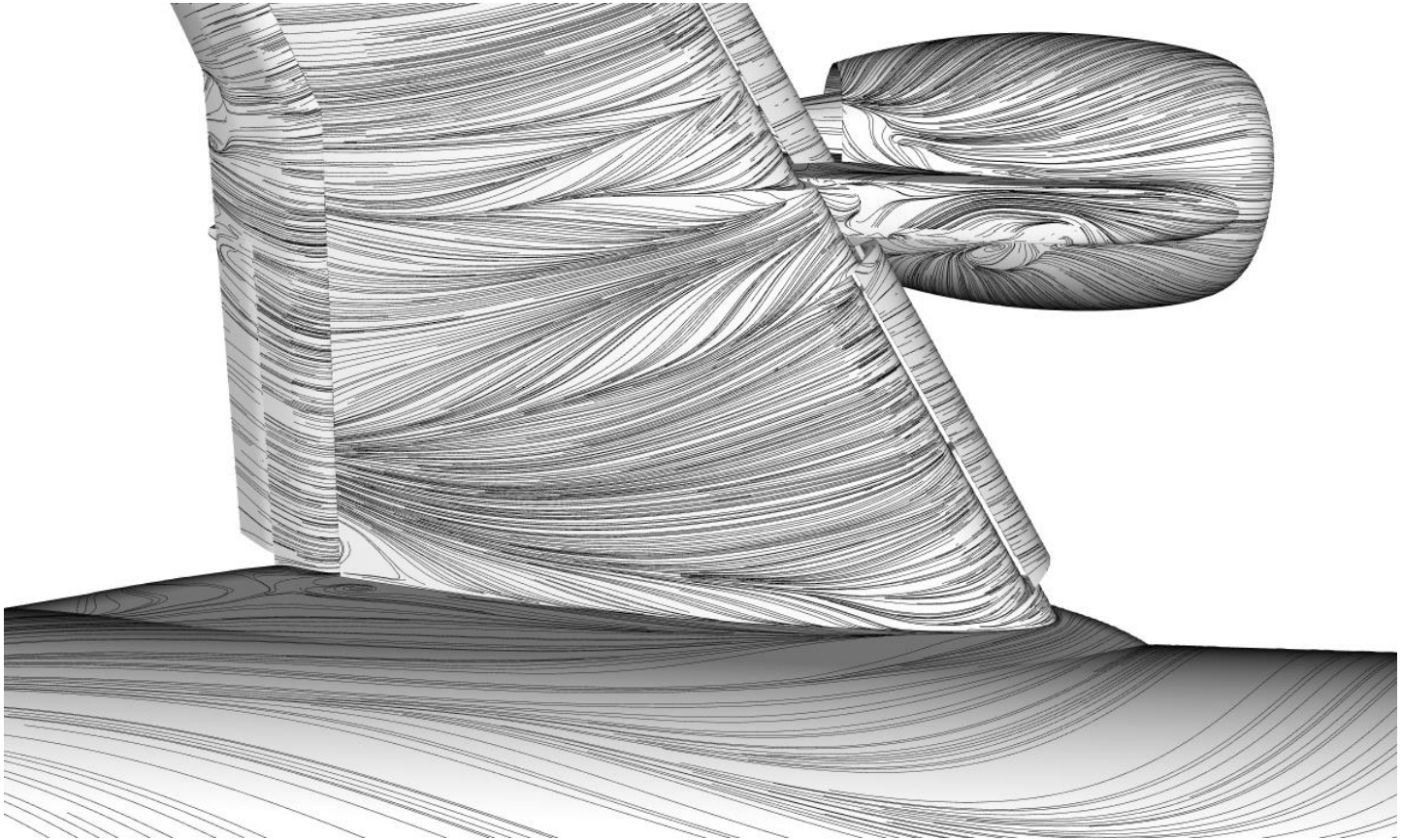

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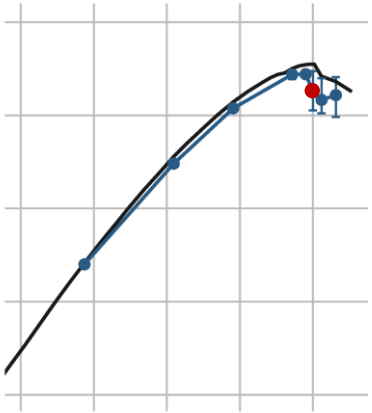
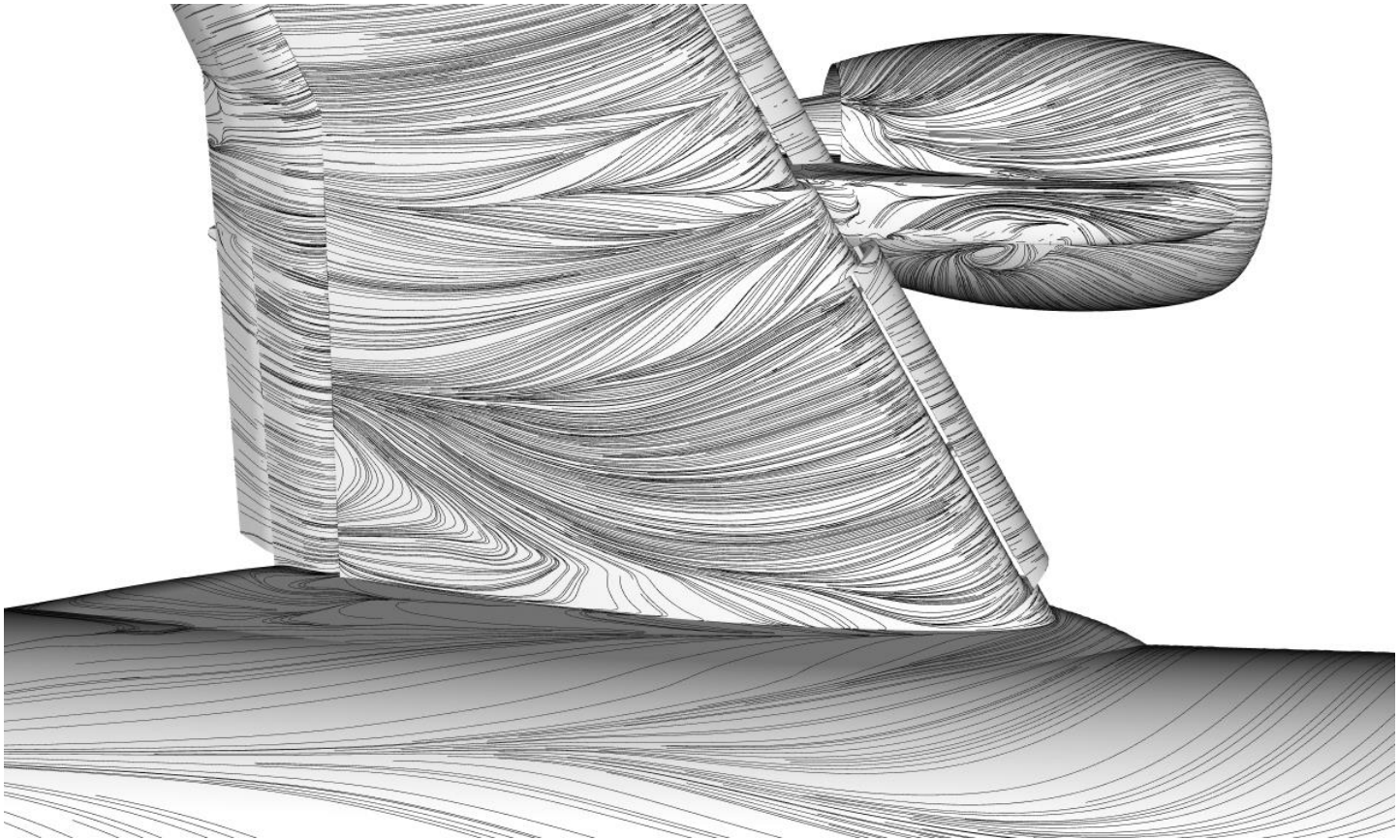
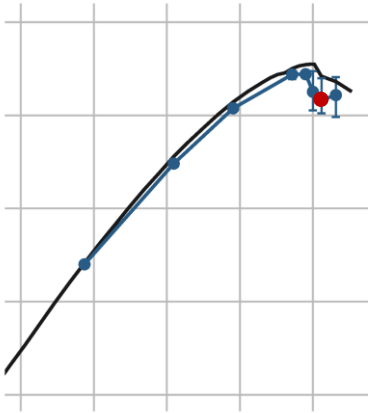
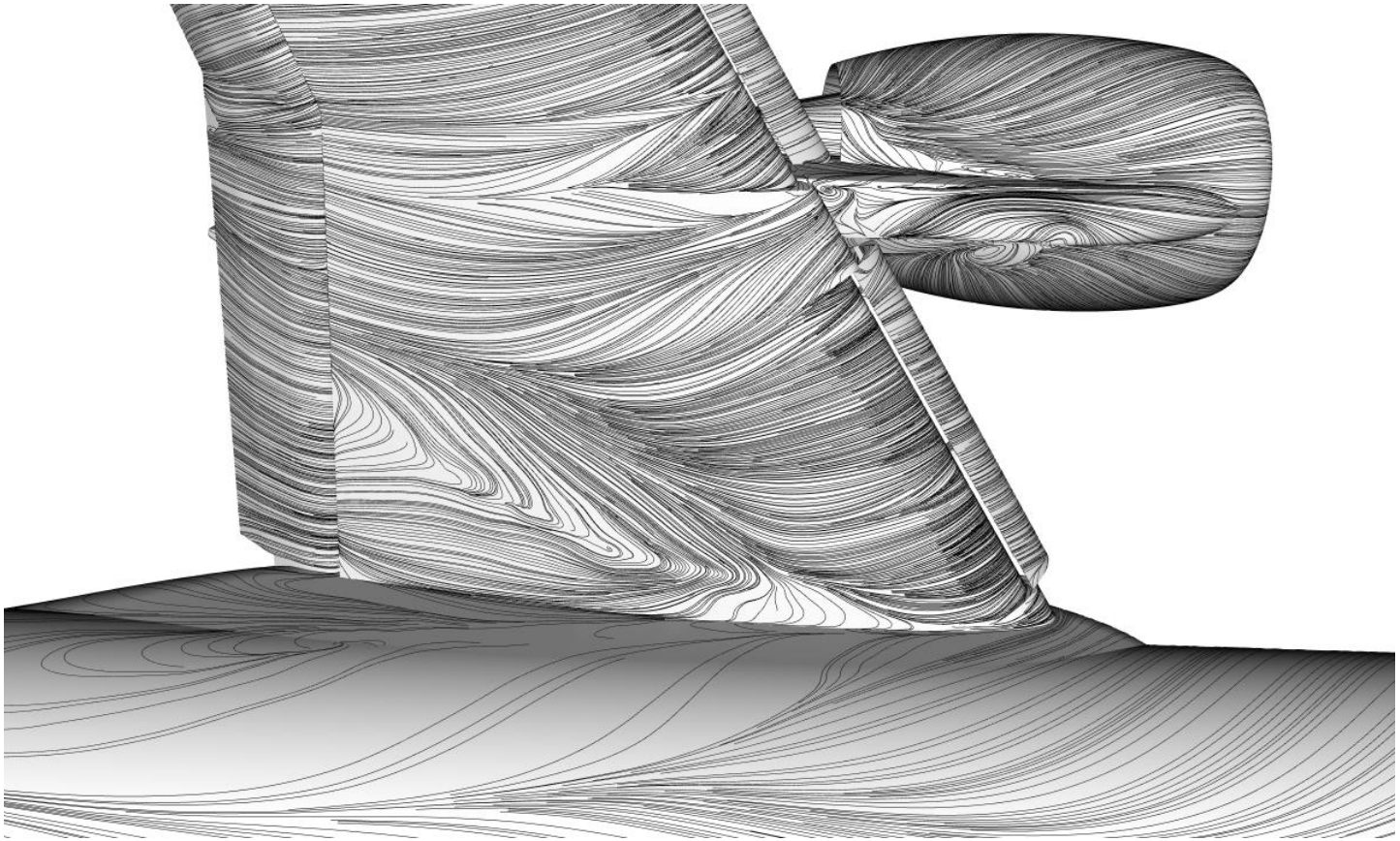




Stall Progression

Use CFD solution to illustrate stall progression





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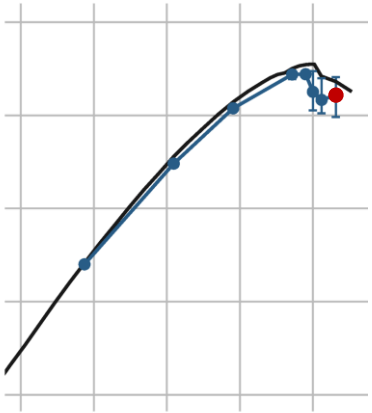

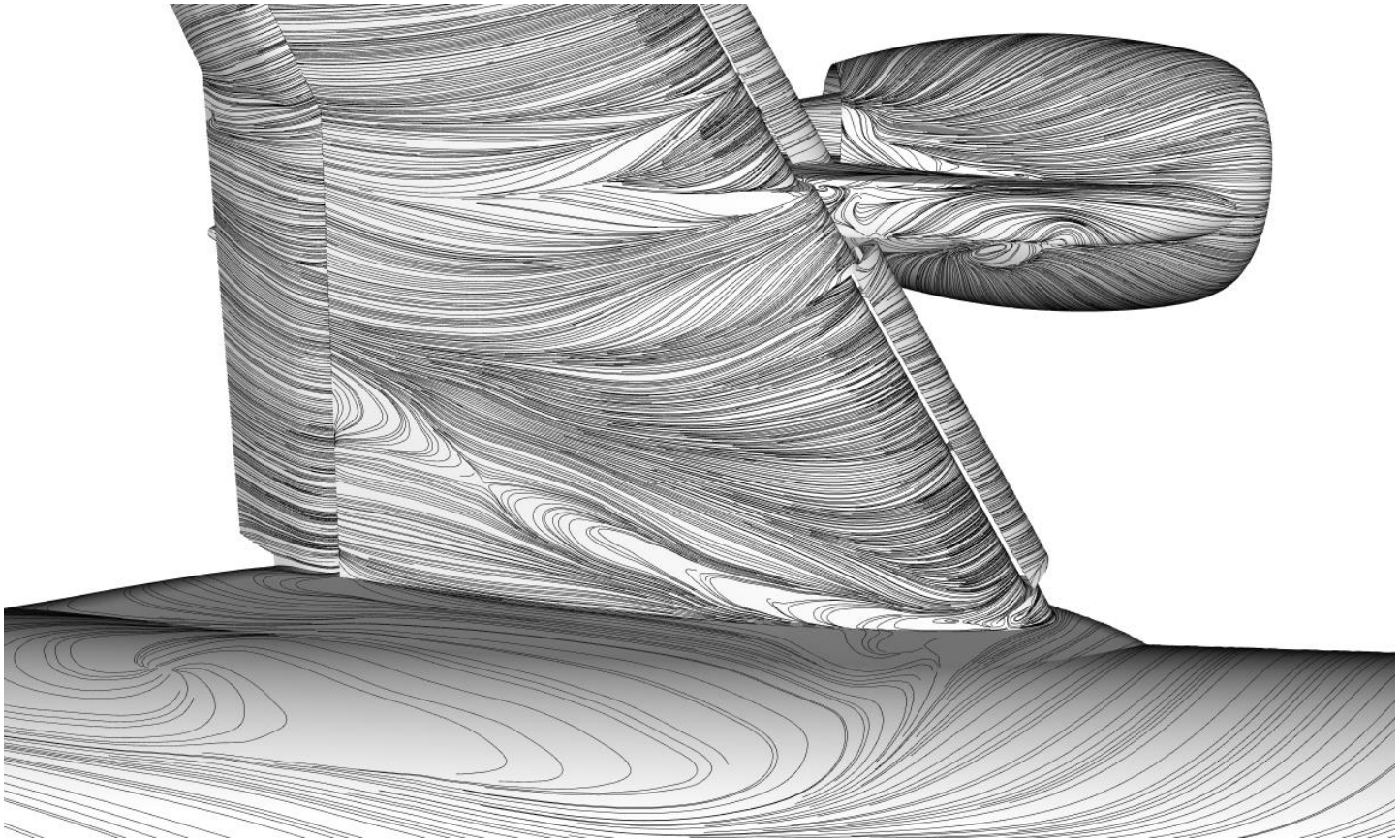

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Summary

- Grid convergence at high angles of attack requires long averaging time
- JSM configuration well suited for CFD validation
  - Wind tunnel interference effects seems small
- Integral forces well matched
  - C_D consistently over-predicted
  - Nacelle/pylon effect well captured
  - C_{Lmax} good, depending on transition
  - Case-dependent transition effect present
- Flow topology and Cp well matched

Outlook

- Ongoing collaborative project with JAXA
- Current/future investigations include:
  - Transition effect
  - Wind tunnel installation effects, especially taking stand-off height into account
  - Reynolds number scaling effects

Thank you